Multiport Measurements using Vector Network Analyzer ZVR

Application Note 1EZ37_1E

Subject to change

10 October 1997, Olaf Ostwald

Products:

ZVR with option ZVR-B8, ZVR-B14 or ZVR-B26

ZVRE with option ZVR-B8, ZVR-B14 or ZVR-B26

ZVRL with option ZVR-B8

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1 Abstract

Using the optional *three-port* or *four-port adapter* (ZVR-B8 and ZVR-B14), PORT 1 and PORT 2 of the network analyzers of the ZVR family (ZVRL, ZVRE and ZVR) can be expanded to up to four ports. Thus automatic measurements on **three- and four-port DUTs** can be easily performed without any reconnection of ports being required. With the electronic switches in the adapters, switchover between the various ports is fast to the extent that the known high measurement and display speed of the analyzers of the ZVR family is fully maintained.

2 Overview

Four different **options** permit measurements on **three- or four-port networks** to be performed:

- **ZVR-B8:** ***Three-Port Adapter***
- **ZVR-B14 model 02:** ***Four-Port Adapter*** **"2 x SPDT"**
- **ZVR-B14 model 03:** ***Four-Port Adapter*** **"SP3T"**
- **ZVR-B26:** ***Extra Inputs, 4-Port***

Each option offers different advantages which will be described in the following.

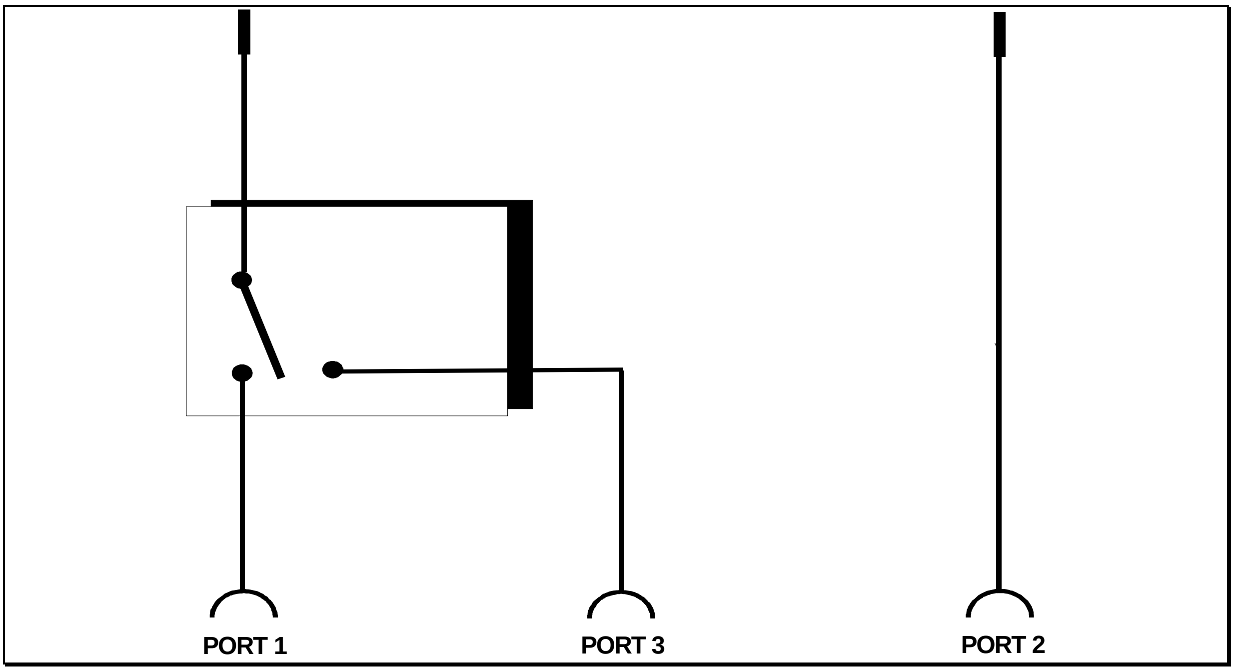

FIG. 1: Drawing on cover of *3-Port Adapter* ZVR-B8

3 Three-Port Measurements

The *3-port adapter* is an optional extra to be used with **all** Network Analyzers of the ZVR family, ie ZVRL, ZVRE and ZVR. It extends PORT 1 and PORT 2 of the network analyzer to **three ports, PORT 1, PORT 2 and PORT 3**. It is provided with an electronic switch which connects PORT 1 of the analyzer to PORT 1 or PORT 3 of the *3-port adapter. PORT 2* of the analyzer is directly connected to the PORT 2 of the adapter and is not switched. The *3-port adapter* is driven via an optional interface at the rear.

3.1 Description of *3-Port Adapter*

Design and function of the *3-port adapter* can be seen from the drawing on the adapter cover (see FIG. 1). The adapter comprises an electronic switch (SPDT = single pole double throw) with field-effect transistors permitting signals between 9 kHz and 4 GHz to be switched virtually wattless and without delay. Its insertion loss is typically 1.6 dB at 9 kHz and increases to approx. 4.2 dB at 4 GHz. The deactivated port, eg PORT 3 (with PORT 1 through-connected), is terminated with a low-reflection 50 Ω resistor.

The *3-port adapter* is driven with the TTL signal CHNBIT0 via the optional rear-panel MULTIPORT ADAPTER interface (former name: 3-PORT ADAPTER). In analyzers of the ZVR family, the status of this signal changes synchronously with the active display channel (CH 1 to CH 4) if the **decoupled channels** mode is selected, ie:

[SWEEP]: COUPLED CHANNELS = OFF.

- For the two **odd display channels**, ie CH 1 and CH 3, the switch is in position **PORT 1**.
- For the two **even display channels**, ie CH 2 and CH 4, the switch is in position **PORT 3**.

3.2 Use

The *3-port adapter* is particularly suitable for measuring special three-port DUTs such as **antenna diplexers**. In practice, a transmitter signal is applied to the first port of the diplexer. The signal is then routed through the diplexer to the second port which is normally connected to a transmitting/receiving antenna. The received signal is routed through the diplexer to the third port to which a receiver is normally connected.

For measurements on the antenna diplexer, the generator input of the diplexer is connected to PORT 1, the antenna input/output to PORT 2 and the receiver output to PORT 3 of the *3-port adapter*. If a bidirectional network analyzer, ie ZVRE or ZVR, is used, the reflection can be measured at all three ports of the diplexer, as well as the transmission between port 1 and port 2 and that between port 2 and port 3 and vice versa. (With the unidirectional Network Analyzer ZVRL only the forward S-parameters S_{11}, S_{21}, S_{23} and S_{33} can of course be measured). Direct measurement of transmissions between port 1 and port 3 is not possible because the two ports are connected to the same analyzer port, ie PORT 1, through the switch of the three-port adapter.

Thus the *3-port adapter* permits seven of the three times three - ie nine - S-parameters of a three-port DUT to be directly measured without the need to reconnect the DUT. The seven parameters are written in bold in the following general S-parameters matrix of any three-port device.

$$(S) = \begin{pmatrix} \mathbf{S_{11}} & \mathbf{S_{12}} & S_{13} \\ \mathbf{S_{21}} & \mathbf{S_{22}} & \mathbf{S_{23}} \\ S_{31} & \mathbf{S_{32}} & \mathbf{S_{33}} \end{pmatrix}$$

The two remaining S-parameters S_{13} and S_{31} may be measured after reconnecting the DUT. However, these parameters need not be known in practical applications. With the aid of the *3-port adapter* all key S-parameters of a DUT can be measured quasi simultaneously. Up to four S-parameters can be displayed at the same time on the network analyzer next to or on top of each other.

A **typical measurement example** is the simultaneous test of the two transmission paths of a diplexer. If, for instance, the transmission coefficient S_{21} from PORT 1 to PORT 2 and S_{23} from PORT 3 to PORT 2 is to be measured, S_{21} can be displayed in channel CH 1 (PORT 1 through-connected) and S_{23} in channel CH 2 (PORT 3 through-connected). Switchover between the two decoupled display channels and therefore between the two measurement paths of the diplexer is performed automatically after each sweep. For example, with 400 test points per channel and a measurement bandwidth of 10 kHz, a switchover is performed every 200 ms. Thus changes in the transmission characteristics of the diplexer can be followed on the analyzer display in real time and the DUT can be adjusted without delay.

Note:

*Regarding the **S-parameter display**, the value indicated at the very left in the top line of the analyzer display always refers to test ports PORT 1 and PORT 2 of the analyzer irrespective of whether a 3-port adapter is used or not and of the adapter switch position.*

Consequently, S21 will always be displayed irrespective of whether S_{21} or S_{23} is measured, as in both cases the forward transmission coefficient from PORT 1 to PORT 2 of the network analyzer is measured.

Additional parameters can be displayed in the other available display channels. For instance, the match S_{11} of the DUT at PORT 1 can be displayed in channel CH 3 (PORT 1 through-connected) and the match S_{33} at PORT 3 in display channel CH 4 (PORT 3 through-connected).

A **combination of two *3-port adapters*** allows also further measurements to be performed. For instance, if the switch input of one *3-port adapter* is connected to PORT 1 of the network analyzer, and the second *3-port adapter* to PORT 2 of the analyzer, two two-port DUTs can be measured simultaneously. Thus the DUTs can be directly compared and easily adjusted. The two *3-port adapters* are driven in parallel from the rear analyzer interface via a simple Y cable.

Other applications are also possible provided the *3-port adapter* is not driven with the previously mentioned TTL signal CHNBIT0 but with the alternative TTL signal CHNBIT1 which is also available at the rear analyzer interface. In this case a minor modification has to be made on the control board of the *3-port adapter.* The CHNBIT1 signal too changes its state synchronously with the active display channel but it assumes one status for the two lower channels CH 1 and CH 2 and the other for the two higher channels CH 3 and CH 4. This means that the switch is in position PORT 1 when display channel CH 1 or CH 2 is active and in position PORT 3 when display channel CH 3 or CH 4 becomes active.

If two *3-port adapters* are used, one driven with a CHNBIT0 and the other with a CHNBIT1 signal, 4-port DUTs can be measured. If, for instance, ports 1 and 2 of the DUT are connected to the first *3-port adapter* and ports 3 and 4 to the second, reflection coefficients can be measured at all four ports of the DUT. Eight of the twelve transmission coefficients can be measured as can be seen in TABLE 1 below.

Display channel	CH 1	CH 2	CH 3	CH 4
CHN BIT 1	1	1	0	0
CHN BIT 0	1	0	1	0
Switch position	PORT 1	PORT 3	PORT 1	PORT 3
4-port S-param.	S_{31} and S_{13}	S_{32} and S_{23}	S_{41} and S_{14}	S_{42} and S_{24}

TABLE 1: Four-port measurement using two *3-port adapters*

To **enhance the measurement accuracy,** a commonly used error correction method, eg TOM, can be used. It is recommended to perform a separate calibration in each of the decoupled display channels. During operation, an automatic switchover between the associated, independent calibration data sets is performed synchronously with the channel change and the switchover of the *3-port adapter.* Switching is fast to the extent that the high measurement speed of the network analyzers of the ZVR family is fully maintained.

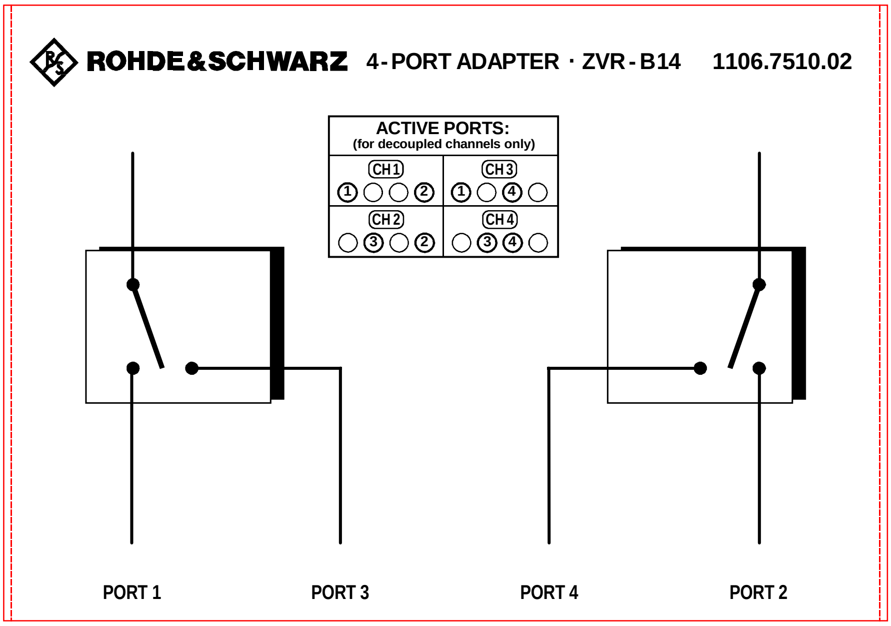

FIG. 2: Drawing on cover of model **02** of *4-Port Adapter* ZVR-B14

4 Four-Port Measurements

The *4-port adapter* is used to expand test PORT 1 and test PORT 2 of the network analyzers of the ZVR family to four ports, PORT 1, PORT 2, PORT 3 and PORT 4. The *4-port adapter* comes in two models (**02** and **03**) with different switching functions so the models are suitable for particular types of four-port DUTs.

Model 02 (see FIG. 2) comprises two independent switches (SPDT). The first switches PORT 1 of the analyzer to PORT 1 or PORT 3 of the *4-port adapter*. The second switches PORT 2 of the network analyzer to PORT 2 or PORT 4 of the *4-port adapter*. This adapter module is particularly suitable for measuring DUTs with **two** inputs and **two** outputs such as double-pole switches or directional couplers but also for simultaneous measurements on two two-port DUTs, eg two amplifiers or two filters.

Model 03 (see FIG. 3), by contrast, connects PORT 1 of the network analyzer directly to PORT 1 of the *4-port adapter*, while PORT 2 of the analyzer can be connected to any of the three remaining ports of the *4-port adapter*, PORT 2, PORT 3 or PORT 4. Thus model **03** is particularly suitable for measuring DUTs with one input and **three** outputs or vice versa, eg filter banks, where the transmission coefficient is to be measured between one port and the **three** others.

If a bidirectional network analyzer is used, **both models** of the *4-port adapter* permit simultaneous measurements of the reflection at all four ports of the DUT or measurements of up to four different transmission coefficients or combinations of reflection and transmission measurements. In all cases the complete range of capabilities of the vector network analyzers of the ZVR family, eg a variety of display modes, complex evaluation functions and a wide range of system error calibration methods, can be used independently for any of the four selected parameters.

The *4-port adapter* is powered and driven via the optional **MULTIPORT ADAPTER** interface (former name: 3-PORT ADAPTER) of the network analyzer.

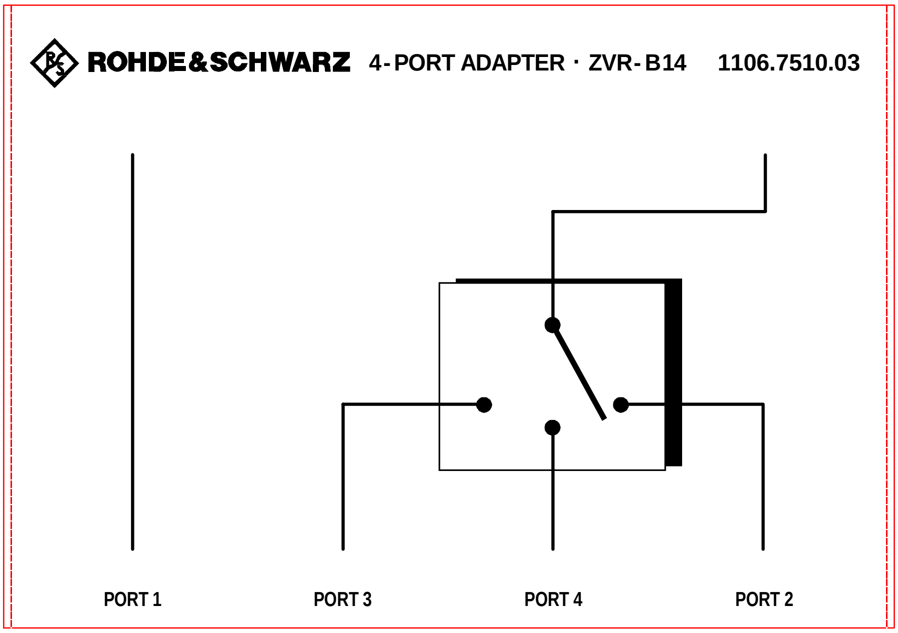

FIG. 3: Drawing on cover of model **03** of *4-Port Adapter* ZVR-B14

4.1 Description of *4-Port Adapters*

As already mentioned, the *4-port adapter* comes in **two models**, **model 02** and **model 03**. Both comprise two electronic switches which are, however, differently wired so that different functions are obtained at their interfaces.

Design and basic functions can be seen from the drawing on the cover of the respective *4-port adapter.*

Model .02 (see FIG. 2) comprises two switches **(SPDT = single pole double throw)**. One switches PORT 1 of the analyzer to PORT 1 or PORT 3 of the *4-port adapter* (left half of module), the other PORT 2 of the network analyzer to PORT 2 or PORT 4 of the *4-port adapter* (right half of module).

Model .03 (see FIG. 3) also comprises two switches. In contrast to model **02**, in this model PORT 1 of the analyzer is directly connected to PORT 1 of the *4-port adapter* (left section of module) and is not switched. The two electronic switches in the right-hand section of the module are wired such that they act like a 1-to-3 switch **(SP3T = single pole triple throw),** as seen from the outside. Thus PORT 2 of the network analyzer can be switched to PORT 2, PORT 3 or PORT 4 of the *4-port adapter.*

The two electronic switches are made up of FET transistors permitting signals between 9 kHz and 4 GHz to be switched virtually wattless and without delay. The insertion loss in the through-connected path of the electronic switch is typically 1.6 dB at 9 kHz and increases to 4.2 dB at 4 GHz. (With model **03** it should be borne in mind that the insertion loss in the paths to PORT 3 and PORT 4 is twice as high because the switches are series-connected.) The disabled ports of the *4-port adapter*, eg PORT 3 and PORT 4 with PORT 1 and PORT 2 through-connected, are terminated with integrated low-reflection 50 Ω resistors.

4.2 Applications

4.2.1 General

The *4-port adapter* allows a variety of four-port DUTs to be measured (also two two-ports, a three-port and a one-port or four one-ports). A standard four-port DUT is defined by its **scattering matrix** (four times four, ie sixteen S-parameters).

$$\mathbf{(S)} = \begin{pmatrix} \mathbf{S_{11}} & \mathbf{S_{12}} & S_{13} & \mathbf{S_{14}} \\ \mathbf{S_{21}} & \mathbf{S_{22}} & \mathbf{S_{23}} & S_{24} \\ S_{31} & \mathbf{S_{32}} & \mathbf{S_{33}} & \mathbf{S_{34}} \\ \mathbf{S_{41}} & S_{42} & \mathbf{S_{43}} & \mathbf{S_{44}} \end{pmatrix}$$

S-parameters measured with model 02

With each model of the *4-port adapter* all four reflection coefficients S_{11} to S_{44} can be measured provided a bidirectional network analyzer is used. Six or eight of the twelve transmission coefficients S_{12} to S_{43} can be determined, depending on the selected *4-port adapter* model.

M**odel 02** is able to measure eight transmission coefficients. The measurable S-parameters are written in bold in the matrix above. The four remaining transmission coefficients S_{13}, S_{31}, S_{24} and S_{42} cannot be determined directly due to the design of model **02** of the *4-port adapter*. To measure these parameters, the DUT has to be reconnected or model **03** of the *4-port adapter* is to be used.

Model 03 of the *4-port adapter* also measures the four reflection coefficients S_{11} to S_{44} of a four-port network. Six of the twelve transmission coefficients S_{12} to S_{43} can be measured, ie the transmissions coefficient from PORT 1 to the other three ports and vice versa. The measurable S-parameters are printed in bold in the following matrix below. Due to the circuit design of model **03** of the *4-port adapter*, the remaining six transmission coefficients, ie S_{23}, S_{32}, S_{24}, S_{42}, S_{34} and S_{43}, cannot be determined directly.

$$\mathbf{(S)} = \begin{pmatrix} \mathbf{S_{11}} & \mathbf{S_{12}} & \mathbf{S_{13}} & \mathbf{S_{14}} \\ \mathbf{S_{21}} & \mathbf{S_{22}} & S_{23} & S_{24} \\ \mathbf{S_{31}} & S_{32} & \mathbf{S_{33}} & S_{34} \\ \mathbf{S_{41}} & S_{42} & S_{43} & \mathbf{S_{44}} \end{pmatrix}$$

S-parameters measured with model 03

The *4-port adapter* is operated via the optional **MULTIPORT ADAPTER** interface at the rear, which was introduced under the name 3-PORT ADAPTER for the *3-port adapter* and has now been renamed.

Control of the two switches in the *4-port adapter* is such that in the case of **decoupled** ZVR display channels ([SWEEP]: COUPLED CHANNELS = OFF) different paths of the *4-port adapter* are through-connected depending on the activated display channel (channel CH 1, CH 2, CH 3 or CH 4). Models **02** and **03** of the *4-port adapter* behave differently:

The exact assignment of active display channel and through-connected ports of **model 02** can be seen from the table on the cover of the *4-port adapter* (see TABLE 2):

CH 1 ①○○②	CH 3 ①○④○
CH 2 ○③○②	CH 4 ○③④○

TABLE 2: Channel assignment of model **02**

As can be seen, PORT 1 of the *4-port adapter* is activated for the two odd display channels (CH 1 and CH 3) and PORT 3 for the two even channels (CH 2 and CH 4). The left-hand switch of the *4-port adapter* is actuated each time a switchover is performed between the odd and even display channels. The right-hand switch is in position PORT 2 for the two lower channel numbers (CH 1 and CH 2) and in position PORT 4 for the two higher channel numbers (CH 3 and CH 4). The right-hand switch is therefore actuated each time a switchover is made between the two lower and the two higher channels.

During switchover from CH 1 to CH 4 the four possible port combinations of the *4-port adapter* (model **02**) are cyclically activated.

Port designation and channel assignment of **model 02** of the *4-port adapter* are selected so that the CH 1 represents the initial state. In this case PORT 1 and PORT 2 of the network analyzer are directly connected to PORT 1 and PORT 2 of the *4-port adapter*. The adapter ports are of the same construction as the two analyzer test ports. Same as in the *3-port adapter*, PORT 3 of the *4-port adapter* is located next to PORT 1. Thus PORT 1 to PORT 3 of the two adapters are of identical design and function. PORT 1 of the analyzer can be through-connected to PORT 1 or PORT 3 of the *4-port adapter*. Symmetrically, PORT 2 of the analyzer is switched to PORT 2 or PORT 4 using the *4-port adapter*.

Assignment of the active display channel and through-connected test ports of **model 03** can be easily explained: Same as with model **02,** port designations and channel assignment in **model 03** of the *4-port adapter* are such that CH 1 is assumed to be in the initial state. In this case PORT 1 and PORT 2 of the network analyzer are through-connected to PORT 1 and PORT 2 of the *4-port adapter.* The remaining three display channels cause the corresponding ports of the *4-port adapter* to be through-connected, ie PORT 2 for CH 2, PORT 3 for CH 3 and PORT 4 for CH 4. It can thus be seen that PORT 1 of **model 03** is always through-connected (see TABLE 3).

CH 1	CH 3
①○○②	①③○○
CH 2	CH 4
①○○②	①○④○

TABLE 3: Channel assignment of model **03**

Same as with model **02,** PORT 1 and PORT 2 are arranged in the same way as the analyzer test ports. PORT 3 of the *4-port adapter* is next to PORT 1 (as in model **02** and the *3-port adapter*).

4.2.2 Model 02

The following procedure is recommended for **measuring four-port S-parameters** using **model 02** of the *4-port adapter*:

1. For the measurement of **forward transmission coefficients** (S_{21}, S_{23}, S_{41}, S_{43}), the S-parameter S_{21} should be selected as the parameter in all four display channels.

- [MEAS]: S21
- [SWEEP]: COUPLED CHANNELS = OFF
- [DISPLAY]: QUAD CHANNEL QUAD SPLIT

Provided the display channels are **decoupled** and a quad split display is selected, the S-parameters of the DUT are displayed in the following form:

S_{21}	S_{41}
S_{23}	S_{43}

2. For the measurement of **reverse transmission coefficients** (S_{12}, S_{32}, S_{14}, S_{34}) S_{12} should be selected as the parameter in all four display channels. Under the conditions described above the following S-parameters of the DUT are displayed:

S_{12}	S_{14}
S_{32}	S_{34}

3. For the measurement of **reflection coefficients** (S_{11}, S_{22}, S_{33}, S_{44}), S_{11} should, for example, be selected as the parameter in display channels CH 1 and CH 4 and S_{22} in channels CH 2 and CH 3. All four reflection coefficients of the DUT are then displayed in the following form:

S_{11}	S_{44}
S_{22}	S_{33}

Of course, different combination of forward and reverse transmission and reflection coefficients can be simultaneously displayed. The exact configuration is determined by the S-parameter selected in the different display channels and the predefined assignment of active display channels and through-connected test ports.

A **system error calibration** can be performed as usual prior to the measurement to increase the accuracy. In this case it is recommended to perform a calibration separately for each display channel and to connect the calibration standards to the two through-connected ports of the *4-port adapter* (or to the connected test cable). During operation, up to four system-error correction data sets are automatically switched upon the channel change and synchronously with the switching of the *4-port adapter*. The **measurement and switching speed** is in all cases high enough for the DUT to be adjusted without delay.

Note:

*Regarding the **S-parameter display** it should be noted that the S-parameter indicated in the respective quadrant at the very left of the top line of the analyzer display always refers to PORT 1 and PORT 2 of the network analyzer irrespective of whether a 4-port adapter is connected or not or of the switch positions of the adapter.*

Consequently, S21 is always displayed if, for example, S_{21} or even S_{31} is measured, as in both cases the transmission coefficient from PORT 1 to PORT 2 of the network analyzer is measured.

4.2.3 Model 03

For **measuring four-port S-parameters** with **model 03** of the *4-port adapter*, the following procedure is recommended:

1. For the measurement of **forward transmission coefficients** (**S_{21}, S_{31}, S_{41}** of the first column in the **scattering matrix (S)**), parameter S_{21} should be measured first in all four display channels.

- [MEAS]: S21
- [SWEEP]: COUPLED CHANNELS = OFF
- [DISPLAY]: QUAD CHANNEL QUAD SPLIT

Provided the display channels are **decoupled** and a quad split display is selected, the three measurable forward transmission coefficients of the DUT are displayed in the following form:

S_{21}	S_{31}
S_{21}	S_{41}

2. For the measurement of **reverse transmission coefficients** (**S_{12}, S_{13}, S_{14}** in the top line of the **scattering matrix (S)**), S_{12} is selected as test parameter in all four display channels. Under the conditions described above, the three measurable reverse transmission coefficients of the DUT are displayed in the following form:

S_{12}	S_{13}
S_{12}	S_{14}

3. For the measurement of **reflection coefficients** (**S_{11}, S_{22}, S_{33}, S_{44}** in the main diagonal of the **scattering matrix (S)**), S_{11} is selected, for instance, in display channels CH 1 and CH 3 and S_{22} in display channels CH 2 and CH 4. The four reflection coefficients are then displayed in the following form (see also FIG. 4):

S_{11}	S_{33}
S_{22}	S_{44}

Of course, different combination of forward and reverse transmission and reflection coefficients can be simultaneously displayed. The assignment is determined by the S-parameter selected in the different display channels and the predefined configuration of active display channels and through-connected test ports.

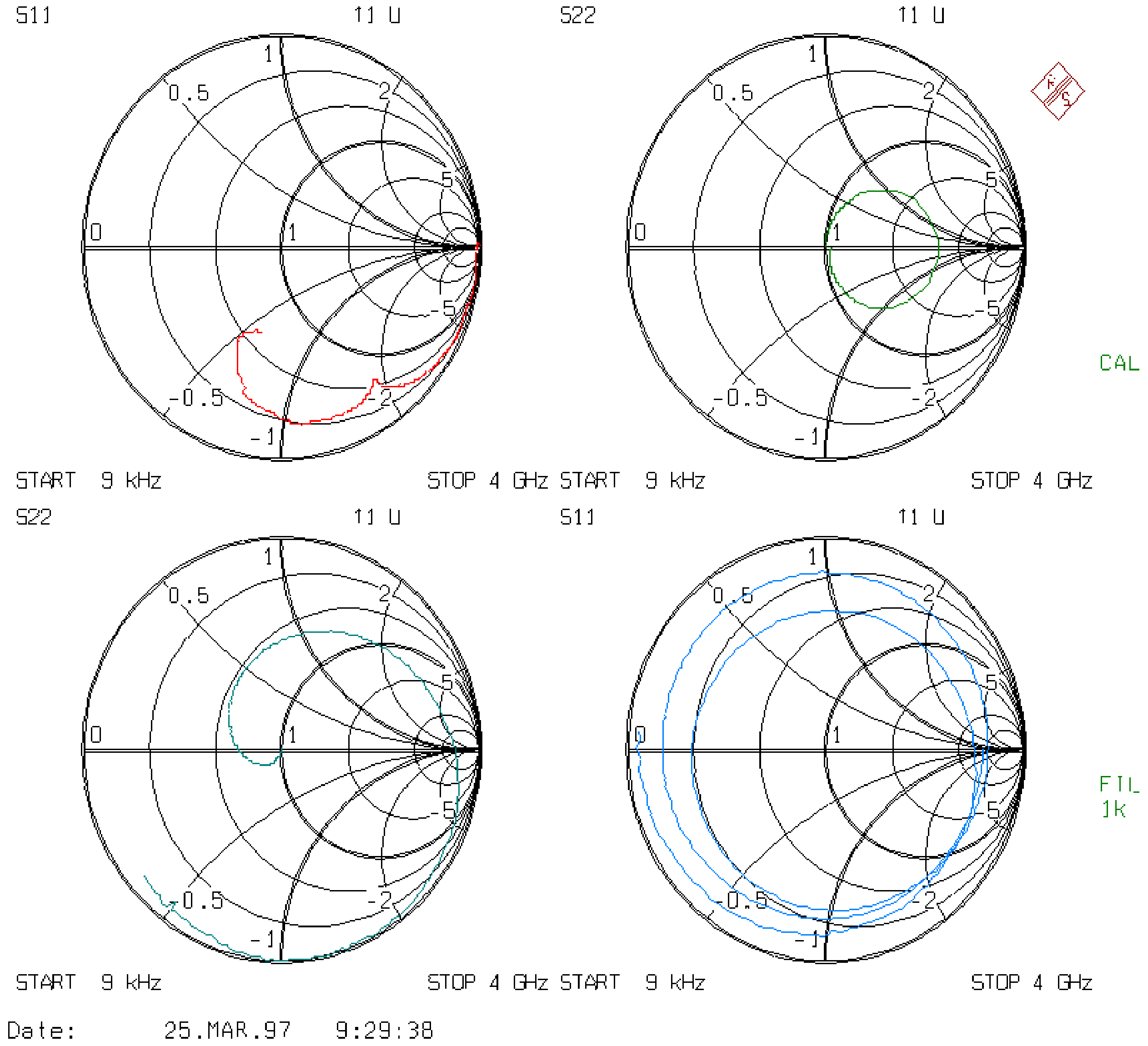

FIG. 4: Simultaneous measurement of the four reflection coefficients of a four-port DUT

To **increase the measurement accuracy,** a system error calibration can be performed as usual prior to the measurement. In this case it is recommended to perform a calibration separately for each display channel and to connect the calibration standards to the two through-connected ports of the *4-port adapter* (or to the test cable connected). During operation, up to four system-error correction data sets are automatically switched upon the channel change and synchronously with the switching of the *4-port adapter*. The **measurement and switching speed** is in all cases high enough for the DUT to be adjusted without delay.

Note:

*Regarding the **display** it should be noted again that the S-parameter indicated in the respective quadrant at the very left of the top line of the analyzer display always refers to PORT 1 and PORT 2 of the network analyzer irrespective of whether a 4-port adapter is connected or not or of the switch positions of the adapter.*

Consequently, S11 is always displayed if, for example, S_{11} or even S_{33} is measured, as in both cases the reflection coefficient at PORT 1 of the network analyzer is measured.

4.3 *Extra Inputs, 4-Port*

The *Extra Inputs* option ZVR-B26 is a third alternative for measurements on four-port networks. In contrast to the *4-Port Adapter* ZVR-B14 described above, no external adapter is connected to PORT 1 and PORT 2 but a modified form of the additional inputs INPUT b1 and INPUT b2 of the *External Measurements* option ZVR-B25 is used as new inputs PORT 3 and PORT 4 for connecting four-port DUTs (see TABLE 4). This option is only available for the bidirectional network analyzers of the ZVR family, ie ZVRE and ZVR.

Front panel:	PORT 1	PORT 2	INPUT b1	INPUT b2
4-port:	PORT 1	PORT 2	PORT 3	PORT 4

TABLE 4: Front panel for option ZVR-B26

PORT 1 and PORT 2 are used as usual as bidirectional test ports, ie they are able to transmit and receive. The new ports PORT 3 and PORT 4 provided by option ZVR-B26 are receiver ports only; they cannot send. Consequently, with this option too only some of the sixteen S-parameters of a 4-port DUT can be measured. The S-parameters for which ports 3 and 4 would be required to send, ie S_{i3} and S_{i4} (i = 1,2,3,4) , cannot therefore be directly measured.

In the scattering matrix below the S-parameters that can be measured with the *Extra Inputs* option ZVR-B26 are written in bold.

$$\mathbf{(S)} = \begin{pmatrix} \mathbf{S_{11}} & \mathbf{S_{12}} & S_{13} & S_{14} \\ \mathbf{S_{21}} & \mathbf{S_{22}} & S_{23} & S_{24} \\ \mathbf{S_{31}} & \mathbf{S_{32}} & S_{33} & S_{34} \\ \mathbf{S_{41}} & \mathbf{S_{42}} & S_{43} & S_{44} \end{pmatrix}$$

The first four parameters S_{11} to S_{22} can be measured as usual with all system error correction methods being available. The remaining four parameters S_{31} to S_{42} are measured in the special 4-port mode of the analyzer. In this case a simple normalization is performed using the trace mathematics. The recommended procedure is illustrated using channel CH 1 and the associated S-parameter S_{31} as an example:

- Connect PORT 1 and PORT 3 directly.

- Press [MODE]: 4-PORT and [CH 1] as well as [MEAS]: S11 to measure S_{31}.

- Press [TRACE]: DATA TO MEMORY: SHOW MATH with MATH = DATA/MEM.

Normalization for this display channel is completed and should be performed analogously for all other display channels. After all four display channels have been normalized, the DUT can be connected and measured. For the **display of the first four S-parameters S_{11} to S_{22}**, the 4-PORT mode is switched off again.

- [MODE]: 4-PORT (softkey is grey again)

To obtain fully corrected test results the trace mathematics and the UNCAL softkey have to be switched off again.

- [TRACE]: SHOW DATA and
- [CAL]: UNCAL (softkey is grey again)

The 4-PORT mode can now be selected again and the **remaining four S-parameters S_{31} to S_{42}** measured in display channels CH 1 to CH 4 using trace mathematics DATA/MEM as described above.

The measured S-parameters of the four-port DUT can be assigned to the respective display channel with the aid of TABLE 5:

Display channel:	CH 1	CH 2	CH 3	CH 4
Softkey designation in MEAS menu:	S11	S21	S12	S22
Measured S-parameter of four-port DUT:	***S31***	***S41***	***S32***	***S42***

TABLE 5: Four-port measurement with ZVR-B26

The described operating steps can of course be performed automatically with the aid of macros or by means of an IEC/IEEE-bus program. If the *Computer Function* option ZVR-B15 is built in, this can be done conveniently on the network analyzer itself without an additional computer being required.

5 Summary

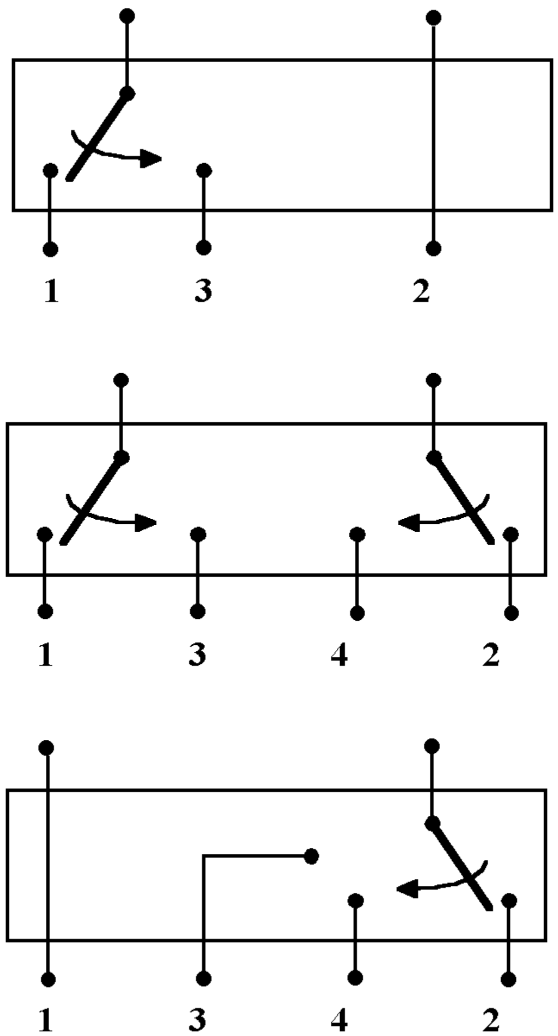

FIG. 5: *3-port adapter* (top)
4-port adapter, model **02** (center)
4-port adapter, model **03** (bottom)

5.1 *3-Port Adapter*

Three-port DUTs can be measured using the *3-Port Adapter* option ZVR-B8 and a Network Analyzer ZVRL (unidirectional only), ZVRE or ZVR. However, due to the construction of the *3-port adapter* (SPDT at PORT 1), S-parameters S_{13} and S_{31} cannot be measured.

$$(S) = \begin{pmatrix} \mathbf{S_{11}} & \mathbf{S_{12}} & S_{13} \\ \mathbf{S_{21}} & \mathbf{S_{22}} & \mathbf{S_{23}} \\ S_{31} & \mathbf{S_{32}} & \mathbf{S_{33}} \end{pmatrix}$$

5.2 *4-Port Adapter,* Model 02

Twelve of the sixteen S-parameters of any **four-port DUT** can be measured when a bidirectional Network Analyzer ZVRE or ZVR is used together with **model 02** of the *4-Port Adapter* option ZVR-B14.

$$\mathbf{(S)} = \begin{pmatrix} \mathbf{S_{11}} & \mathbf{S_{12}} & S_{13} & \mathbf{S_{14}} \\ \mathbf{S_{21}} & \mathbf{S_{22}} & \mathbf{S_{23}} & S_{24} \\ S_{31} & \mathbf{S_{32}} & \mathbf{S_{33}} & \mathbf{S_{34}} \\ \mathbf{S_{41}} & S_{42} & \mathbf{S_{43}} & \mathbf{S_{44}} \end{pmatrix}$$

5.3 *4-Port Adapter,* Model 03

Model 03 of the *4-Port Adapter* option ZVR-B14 is particularly suitable for measurements on **four-port DUTs** when the transmission coefficient from one port to all other ports is to be measured.

$$\mathbf{(S)} = \begin{pmatrix} \mathbf{S_{11}} & \mathbf{S_{12}} & \mathbf{S_{13}} & \mathbf{S_{14}} \\ \mathbf{S_{21}} & \mathbf{S_{22}} & S_{23} & S_{24} \\ \mathbf{S_{31}} & S_{32} & \mathbf{S_{33}} & S_{34} \\ \mathbf{S_{41}} & S_{42} & S_{43} & \mathbf{S_{44}} \end{pmatrix}$$

5.4 *Extra Inputs, 4-Port*

The *Extra Inputs, 4-Port,* option ZVR-B26 is the third alternative for measurements on four-port networks.

$$\mathbf{(S)} = \begin{pmatrix} \mathbf{S_{11}} & \mathbf{S_{12}} & S_{13} & S_{14} \\ \mathbf{S_{21}} & \mathbf{S_{22}} & S_{23} & S_{24} \\ \mathbf{S_{31}} & \mathbf{S_{32}} & S_{33} & S_{34} \\ \mathbf{S_{41}} & \mathbf{S_{42}} & S_{43} & S_{44} \end{pmatrix}$$

In contrast to the other options, no adapter is connected in this case to test ports PORT 1 and PORT 2 of the network analyzer but merely the front panel is extended by two additional test inputs PORT 3 and PORT 4.

Olaf Ostwald, 1ES3
Rohde & Schwarz
10 October 1997

6 Further Application Notes

[1] O. Ostwald: 3-Port Measurements with Vector Network Analyzer ZVR, Appl. Note 1EZ26_1E.

[2] H.-G. Krekels: Automatic Calibration of Vector Network Analyzer ZVR, Appl. Note 1EZ30_1E.

[3] O. Ostwald: 4-Port Measurements with Vector Network Analyzer ZVR, Appl. Note 1EZ25_1E.

[4] T. Bednorz: Measurement Uncertainties for Vector Network Analysis, Appl. Note 1EZ29_1E.

[5] P. Kraus: Measurements on Frequency-Converting DUTs using Vector Network Analyzer ZVR, Appl. Note 1EZ32_1E.

[6] J. Ganzert: Accessing Measurement Data and Controlling the Vector Network Analyzer via DDE, Appl. Note 1EZ33_1E.

[7] J. Ganzert: File Transfer between Analyzers FSE or ZVR and PC using MS-DOS Interlink, Appl. Note 1EZ34_1E.

[8] O. Ostwald: Group and Phase Delay Measurements with Vector Network Analyzer ZVR, Appl. Note 1EZ35_1E.

[9] O. Ostwald: Multiport Measurements using Vector Network Analyzer, Appl. Note 1EZ37_1E.

[10] O. Ostwald: Frequently Asked Questions about Vector Network Analyzer ZVR, Appl. Note 1EZ38_3E.

[11] A. Gleißner: Internal Data Transfer between Windows 3.1 / Excel and Vector Network Analyzer ZVR, Appl. Note 1EZ39_1E.

[12] A. Gleißner: Power Calibration of Vector Network Analyzer ZVR, Appl. Note 1EZ41_2E

[13] O. Ostwald: Pulsed Measurements on GSM Amplifier SMD ICs with Vector Analyzer ZVR, Appl. Note 1EZ42_1E.

[14] O. Ostwald: Zeitbereichsmessungen mit dem Netzwerkanalysator ZVR, Appl. Note 1EZ44_1D.

7 Ordering Information

Order designation	Type	Frequency range	Order No.
Vector Network Analyzers (test sets included) *			
3-channel, unidirectional, 50 Ω, passive	ZVRL	9 kHz to 4 GHz	1043.0009.41
3-channel, bidirectional, 50 Ω, passive	ZVRE	9 kHz to 4 GHz	1043.0009.51
3-channel, bidirectional, 50 Ω, active	ZVRE	300 kHz to 4 GHz	1043.0009.52
4-channel, bidirectional, 50 Ω, passive	ZVR	9 kHz to 4 GHz	1043.0009.61
4-channel, bidirectional, 50 Ω, active	ZVR	300 kHz to 4 GHz	1043.0009.62
3-channel, bidirectional, 50 Ω, active	ZVCE	20 kHz to 8 GHz	1106.9020.50
4-channel, bidirectional, 50 Ω, active	ZVC	20 kHz to 8 GHz	1106.9020.60
Alternative Test Sets *			
75 Ω SWR Bridge for ZVRL (instead of 50 Ω) [1)]			
75 Ω, passive	ZVR-A71	9 kHz to 4 GHz	1043.7690.18
75 Ω SWR Bridge Pairs for ZVRE and ZVR (instead of 50 Ω) [1)]			
75 Ω, passive	ZVR-A75	9 kHz to 4 GHz	1043.7755.28
75 Ω, active	ZVR-A76	300 kHz to 4 GHz	1043.7755.29
Options			
AutoKal	ZVR-B1	0 to 8 GHz	1044.0625.02
Time Domain	ZVR-B2	same as analyzer	1044.1009.02
Mixer Measurements [2)]	ZVR-B4	same as analyzer	1044.1215.02
Reference Channel Ports	ZVR-B6	same as analyzer	1044.1415.02
Power Calibration [3)]	ZVR-B7	same as analyzer	1044.1544.02
3-Port Adapter	ZVR-B8	0 to 4 GHz	1086.0000.02
Virtual Embedding Networks [4)]	ZVR-K9	same as analyzer	1106.8830.02
4-Port Adapter (2xSPDT)	ZVR-B14	0 to 4 GHz	1106.7510.02
4-Port Adapter (SP3T)	ZVR-B14	0 to 4 GHz	1106.7510.03
Controller (German) [5)]	ZVR-B15	-	1044.0290.02
Controller (English) [5)]	ZVR-B15	-	1044.0290.03
Ethernet BNC for ZVR-B15	FSE-B16	-	1073.5973.02
Ethernet AUI for ZVR-B15	FSE-B16	-	1073.5973.03
IEC/IEEE-Bus Interface for ZVR-B15	FSE-B17	-	1066.4017.02
Generator Step Attenuator PORT 1	ZVR-B21	same as analyzer	1044.0025.11
Generator Step Attenuator PORT 2 [6)]	ZVR-B22	same as analyzer	1044.0025.21
Receiver Step Attenuator PORT 1	ZVR-B23	same as analyzer	1044.0025.12
Receiver Step Attenuator PORT 2	ZVR-B24	same as analyzer	1044.0025.22
External Measurements, 50 Ω [7)]	ZVR-B25	10 Hz to 4 GHz (ZVR/E/L) 20 kHz to 8 GHz (ZVC/E)	1044.0460.02

[1)] To be ordered together with the analyzer.
[2)] Harmonics measurements included.
[3)] Power meter and sensor required.
[4)] Only for ZVR or ZVC with ZVR-B15.
[5)] DOS, Windows 3.11, keyboard and mouse included.
[6)] For ZVR or ZVC only.
[7)] Step attenuators required.

*** Note:**
Active test sets, in contrast to passive test sets, comprise internal bias ne tworks, eg to supply DUTs.